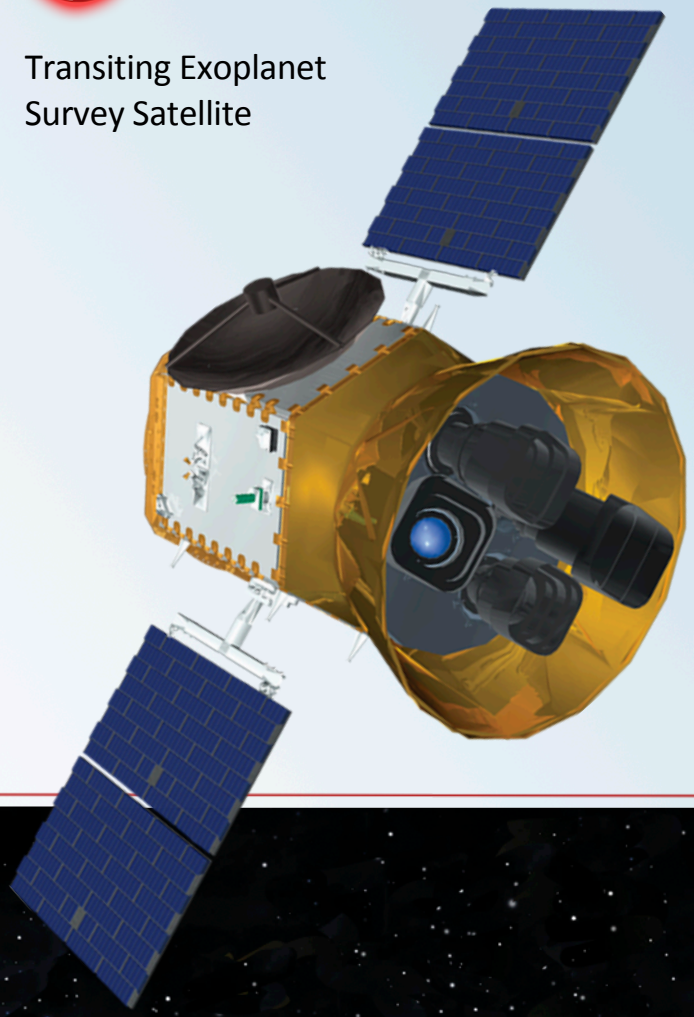
Transiting Exoplanet
Survey Satellite



TESS: Discovering New Earths and Super-Earths in the Solar Neighborhood

George Ricker

31st International Colloquium

From Super-Earths to Brown Dwarfs: Who's Who?

Institut d'Astrophysique de Paris

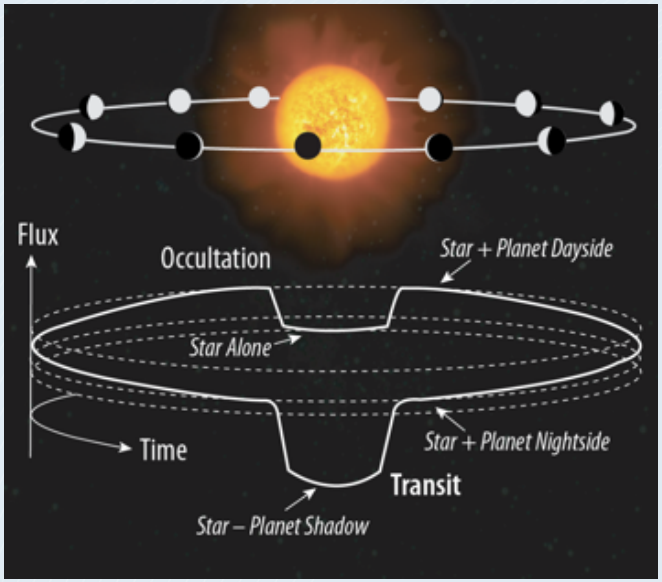
29 June 2015

TESS Institutional Partners

Ames

TESS Science Team

So Many Stars...So Little Time



Primary Goal: Discover Transiting Earths and Super-Earths Orbiting Bright, Nearby Stars

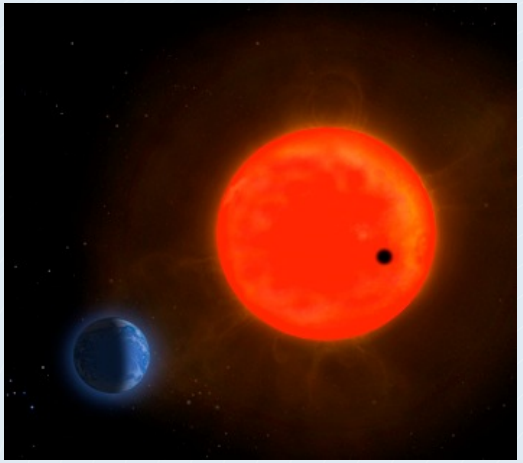
- *Rocky Planets & Water Worlds*
- *Habitable Planets*

Discover the "Best" ~1000 **Small** Exoplanets

- *"Best" Means "Readily Characterizable"*
  - *Bright Host Stars*
  - *Measurable Mass & Atmospheric Properties*
- *Present: Only 3 small transiting exoplanets orbiting bright hosts are known*

Large Area Survey of Bright Stars

- *Sun-like stars: $I_c \lessapprox 2$ to $I_c = 12$ magnitude*
- *M dwarfs known within ~60 parsecs ($I_c \lessapprox 14$)*
- *"All sky" observations in 2 years:*
  - *> 200,000 target stars at <2 min cadence*
  - *> 20,000,000 stars in full frames at 30 min cadence*

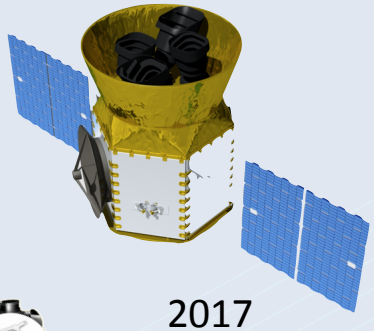


Launch in August 2017

TESS Stars Are Brighter than Kepler Stars

- How do we arrange for brighter stars?
  - *Two ways...*

2009

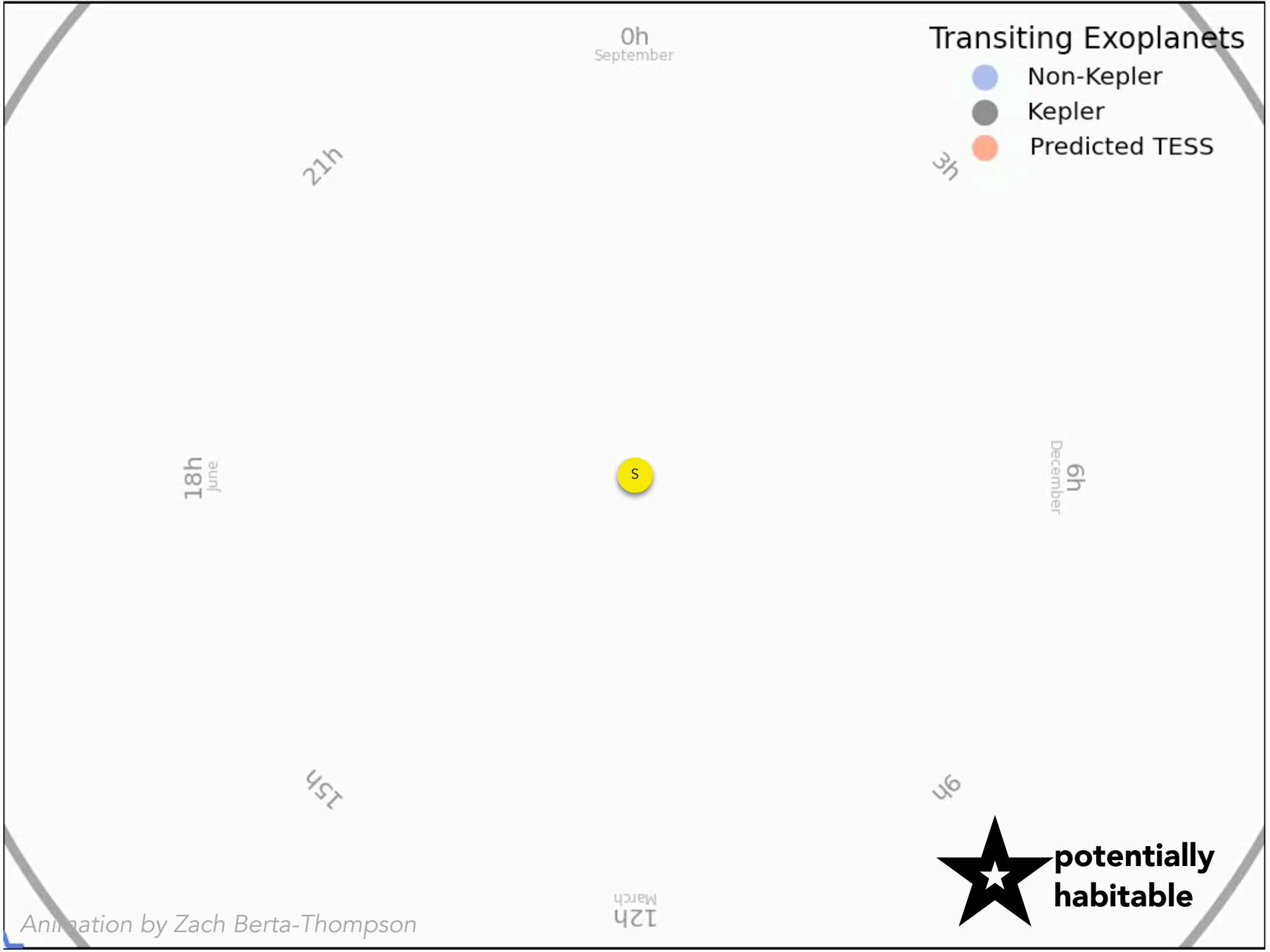


2017

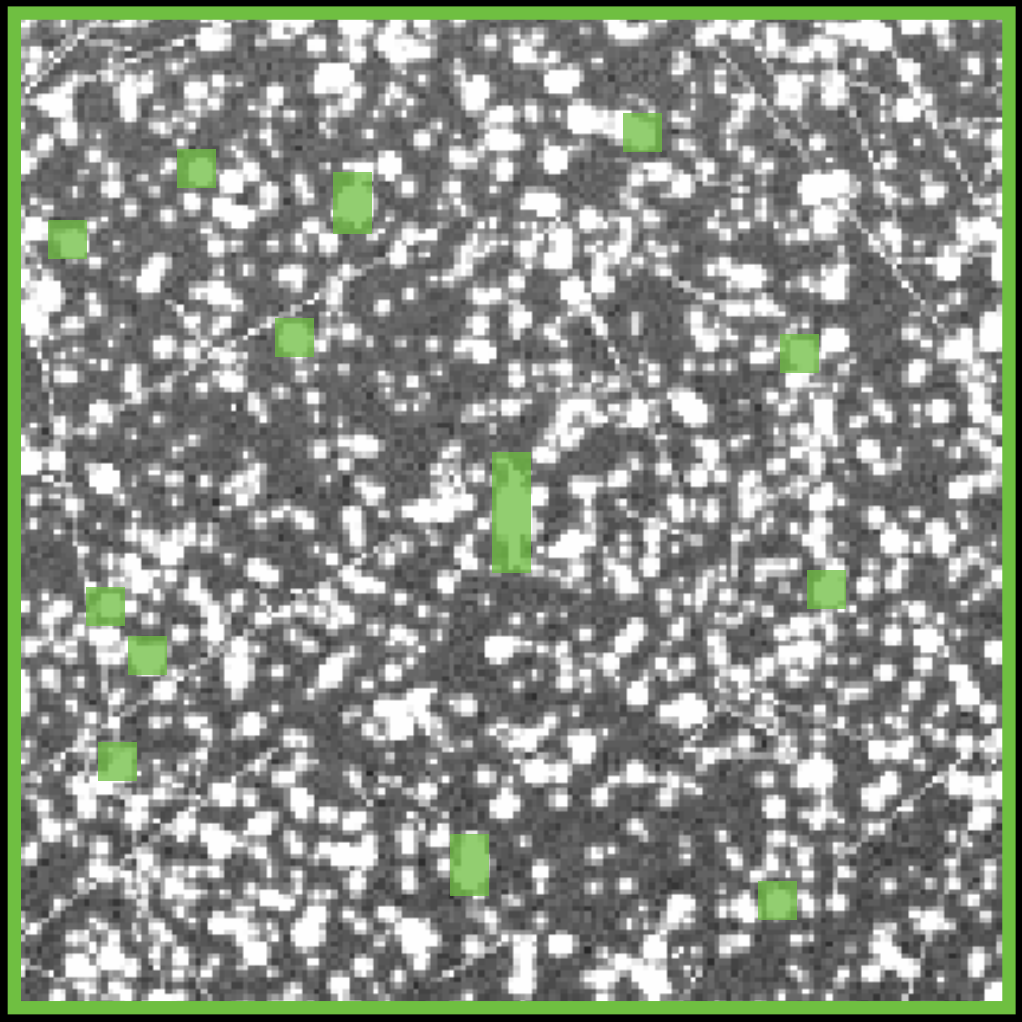
- Increase solid angle coverage
  - $\Omega_{TESS} \simeq 400\ \Omega_{Kepler}$
  - *Number of accessible bright stars increased by same factor*

- Select stars that are much closer
  - *TESS: ~10^2 light-yr*
  - *Kepler: ~10^3 light-yr*

$1/R^2$ dependence means TESS stars are ~100 times brighter on average


0h
September
3h
6h
December
9h
12h
March
15h
18h
June
21h
S
Transiting Exoplanets
Non-Kepler
Kepler
Predicted TESS
potentially habitable
Animation by Zach Berta-Thompson

2-minute cadence
for >200,000 stars

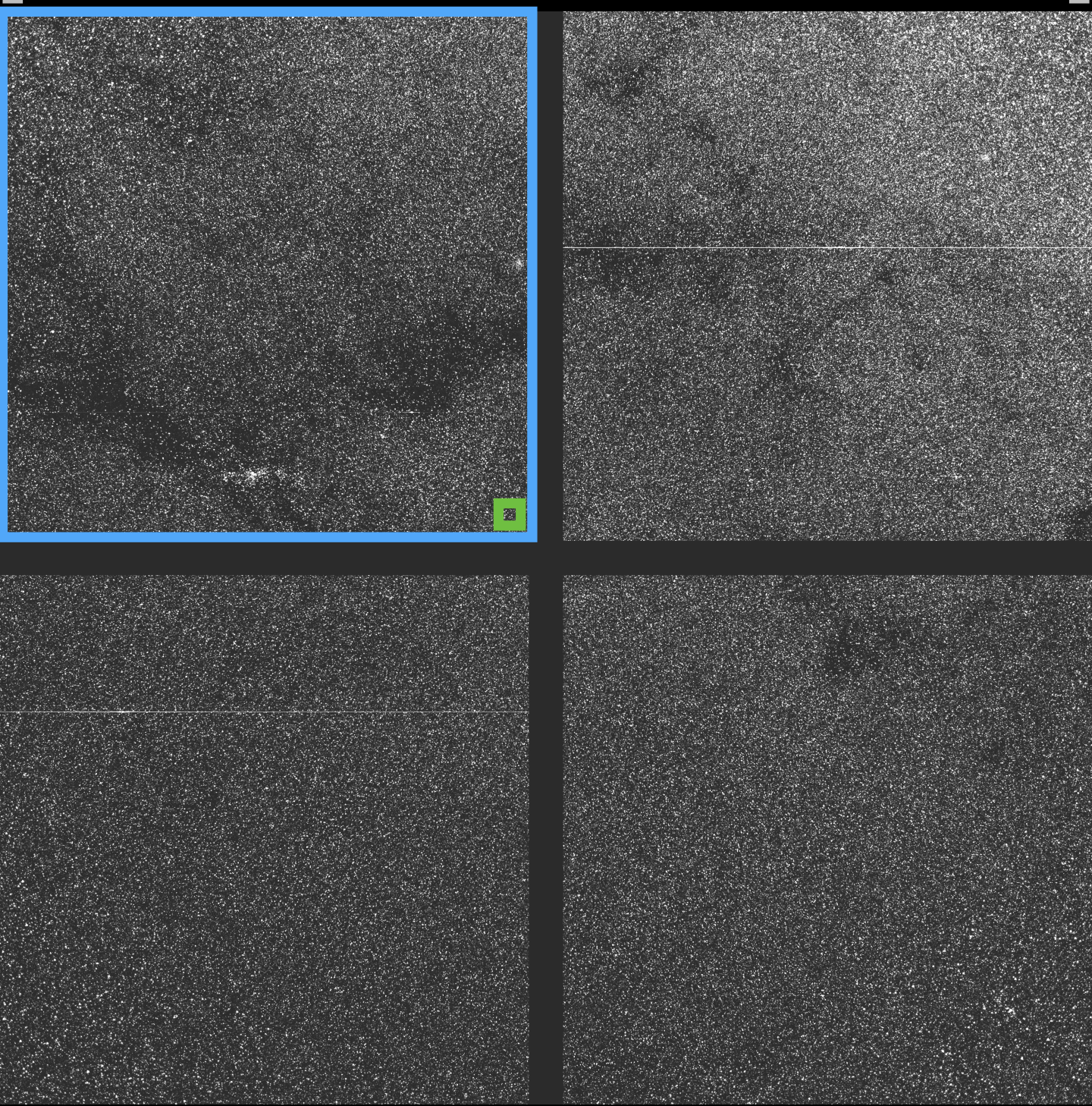


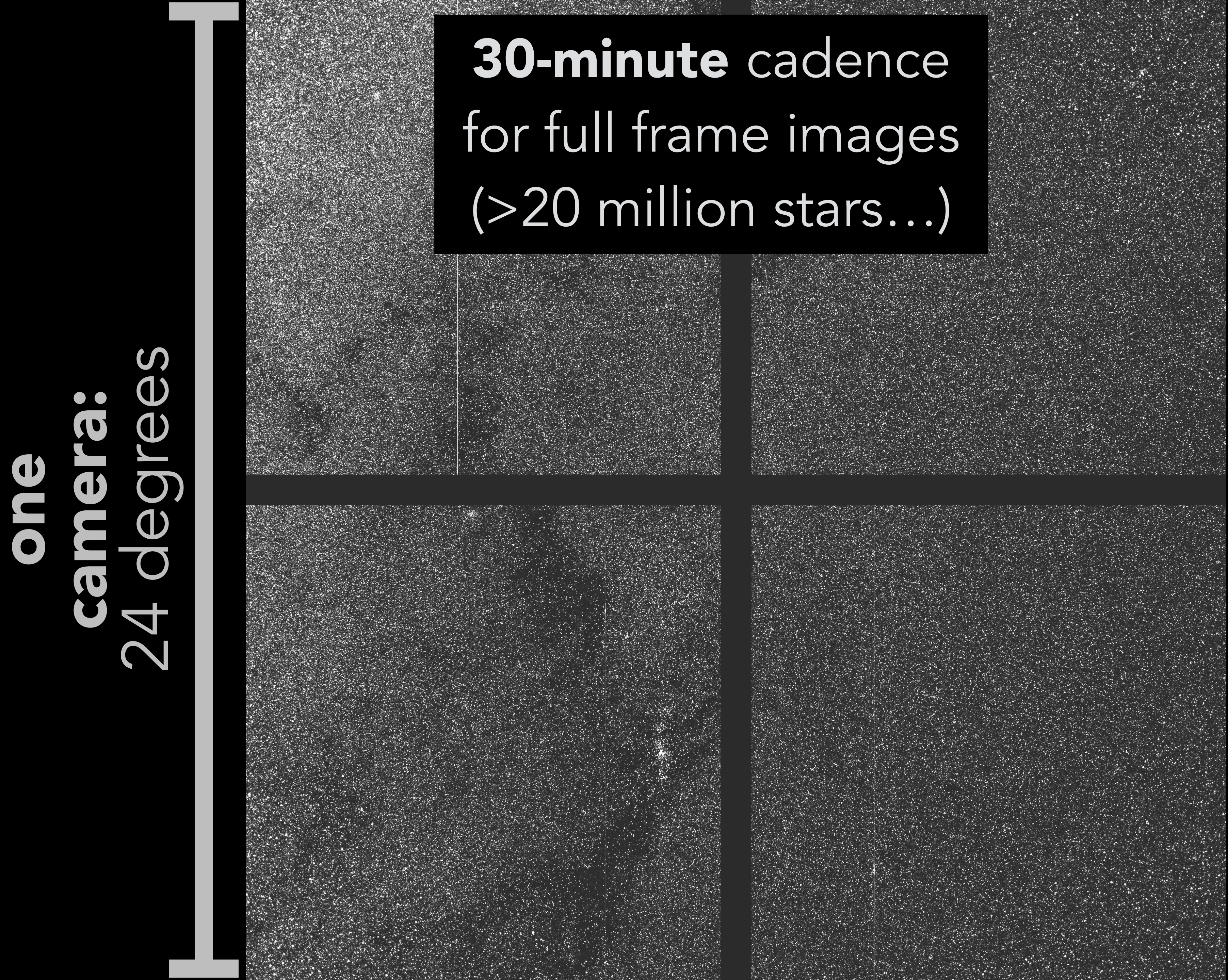
1 degree

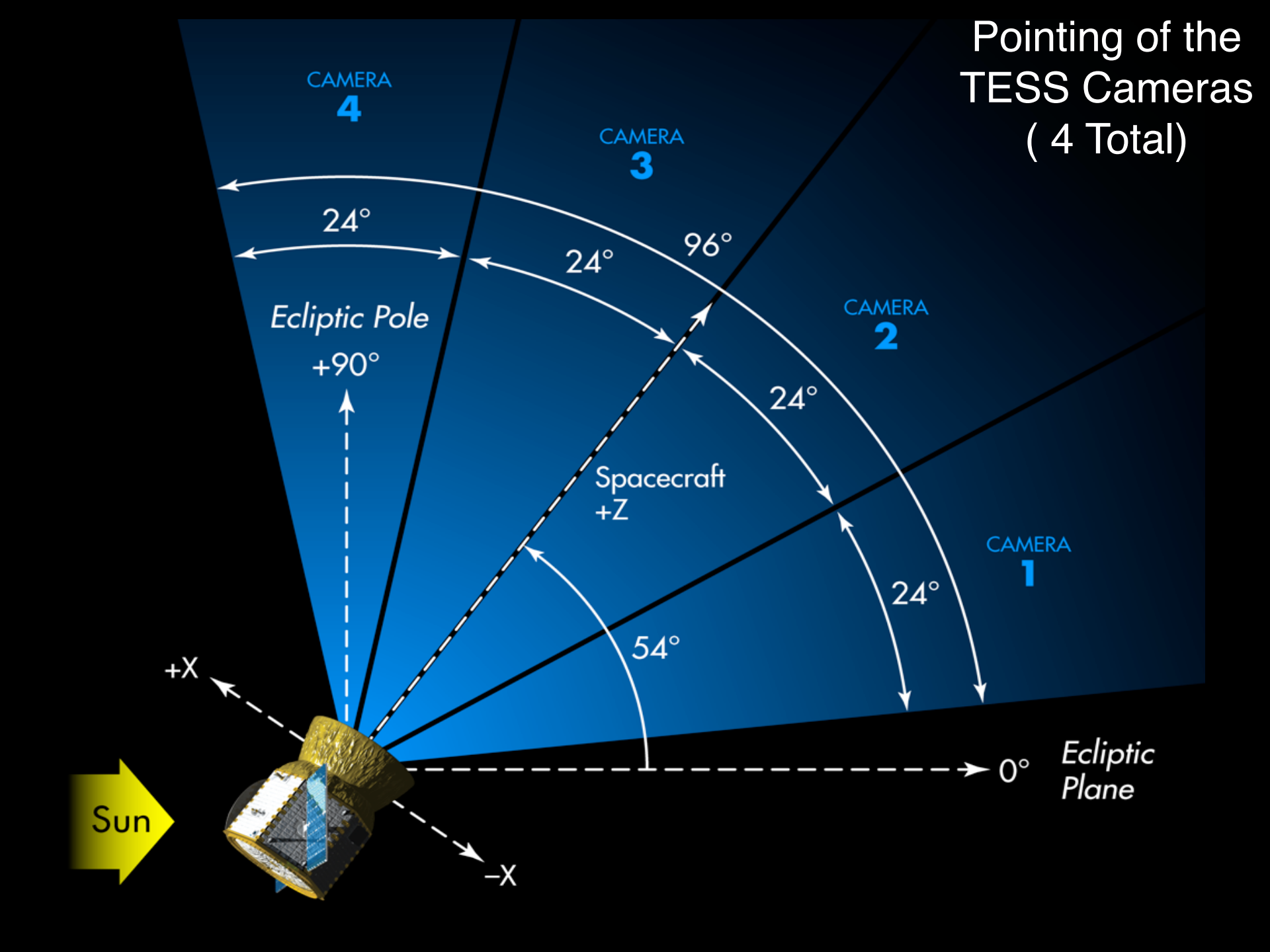
prioritizing
detectability of
small planets

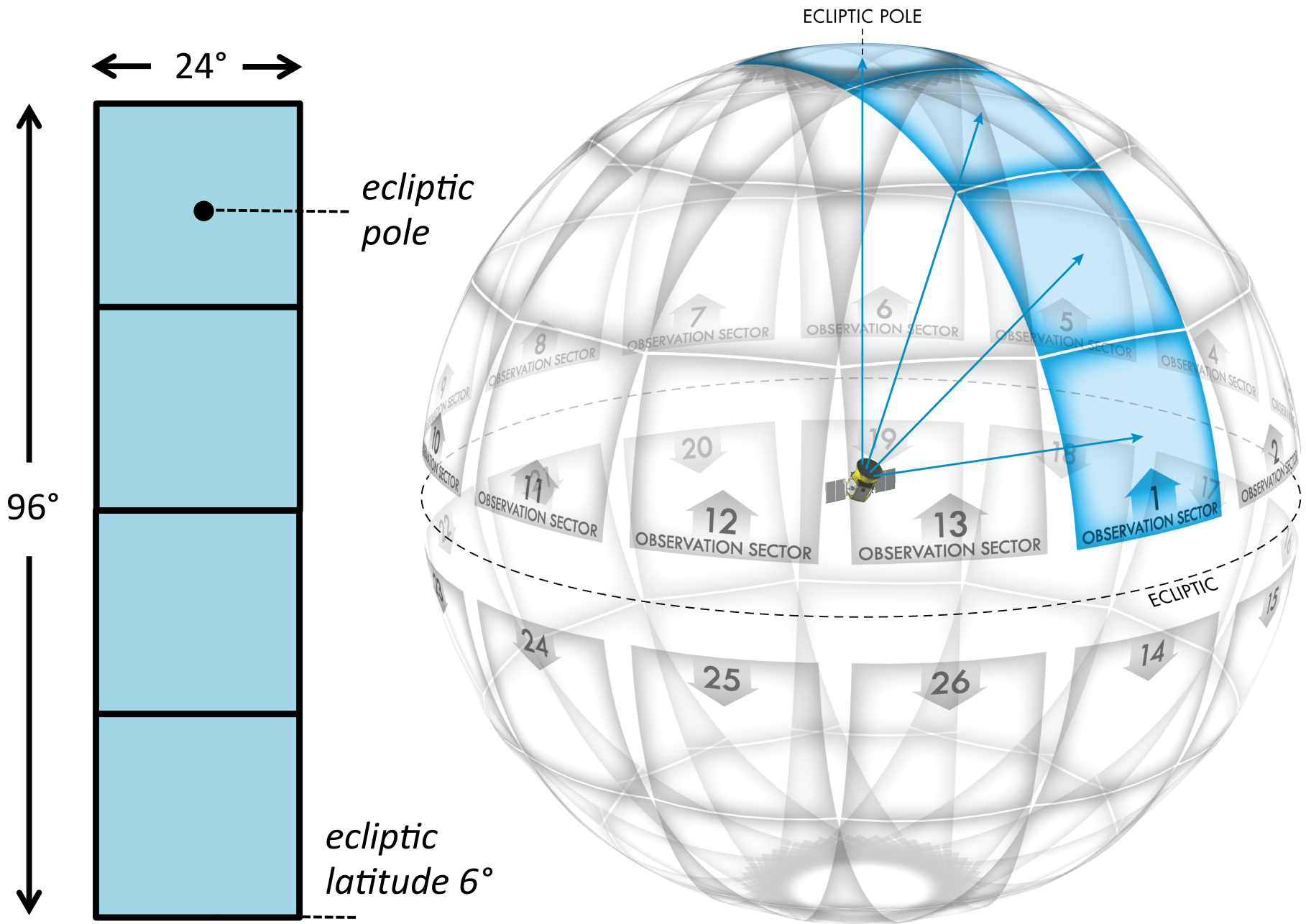
simulated images by Zach Berta-Thompson

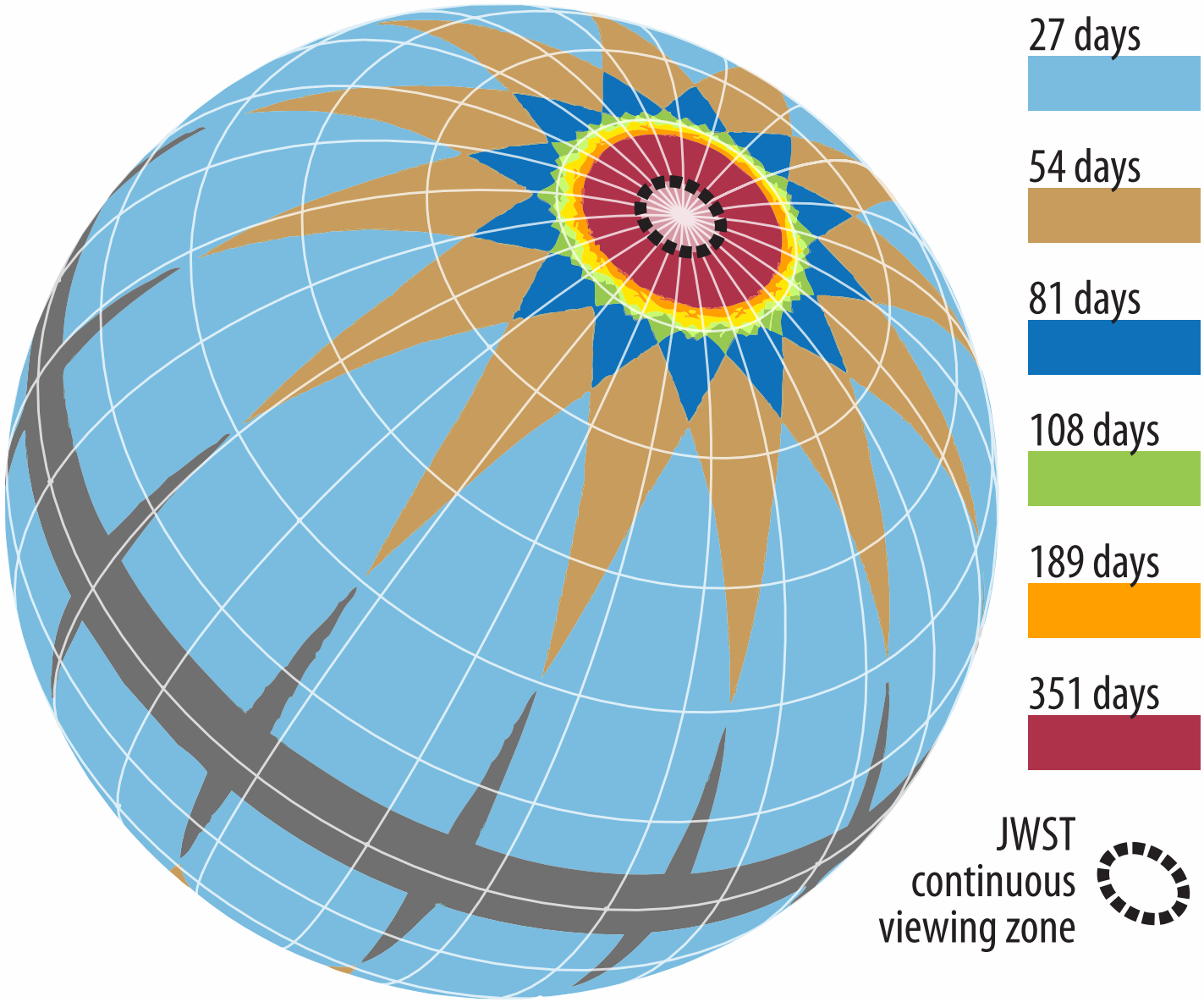
one camera:
24 degrees

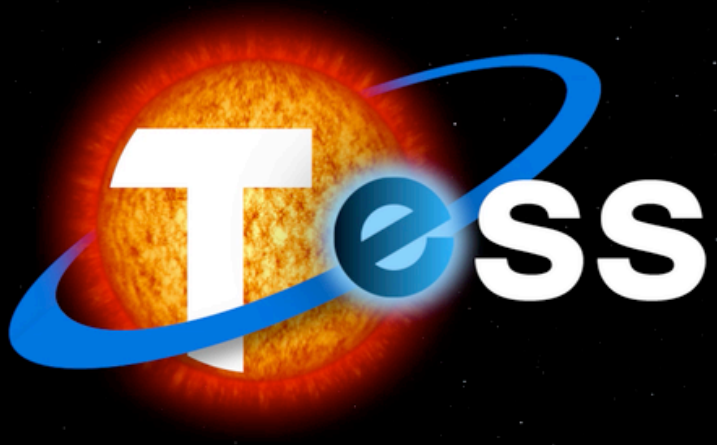



30-minute cadence
for full frame images
(>20 million stars…)
one camera:
24 degrees


Pointing of the TESS Cameras (4 Total)
CAMERA 4
CAMERA 3
CAMERA 2
CAMERA 1
24°
24°
96°
24°
24°
24°
Ecliptic Pole
+90°
Spacecraft +Z
54°
+X
-X
Sun
0°
Ecliptic Plane


24°
96°
ecliptic pole
ecliptic latitude 6°
ECLIPTIC POLE
ECLIPTIC
1 OBSERVATION SECTOR
2 OBSERVATION SECTOR
4 OBSERVATION SECTOR
5 OBSERVATION SECTOR
6 OBSERVATION SECTOR
7 OBSERVATION SECTOR
8 OBSERVATION SECTOR
10 OBSERVATION SECTOR
11 OBSERVATION SECTOR
12 OBSERVATION SECTOR
13 OBSERVATION SECTOR
14
15
17
18
19
20
24
25
26


27 days
54 days
81 days
108 days
189 days
351 days
JWST
continuous
viewing zone



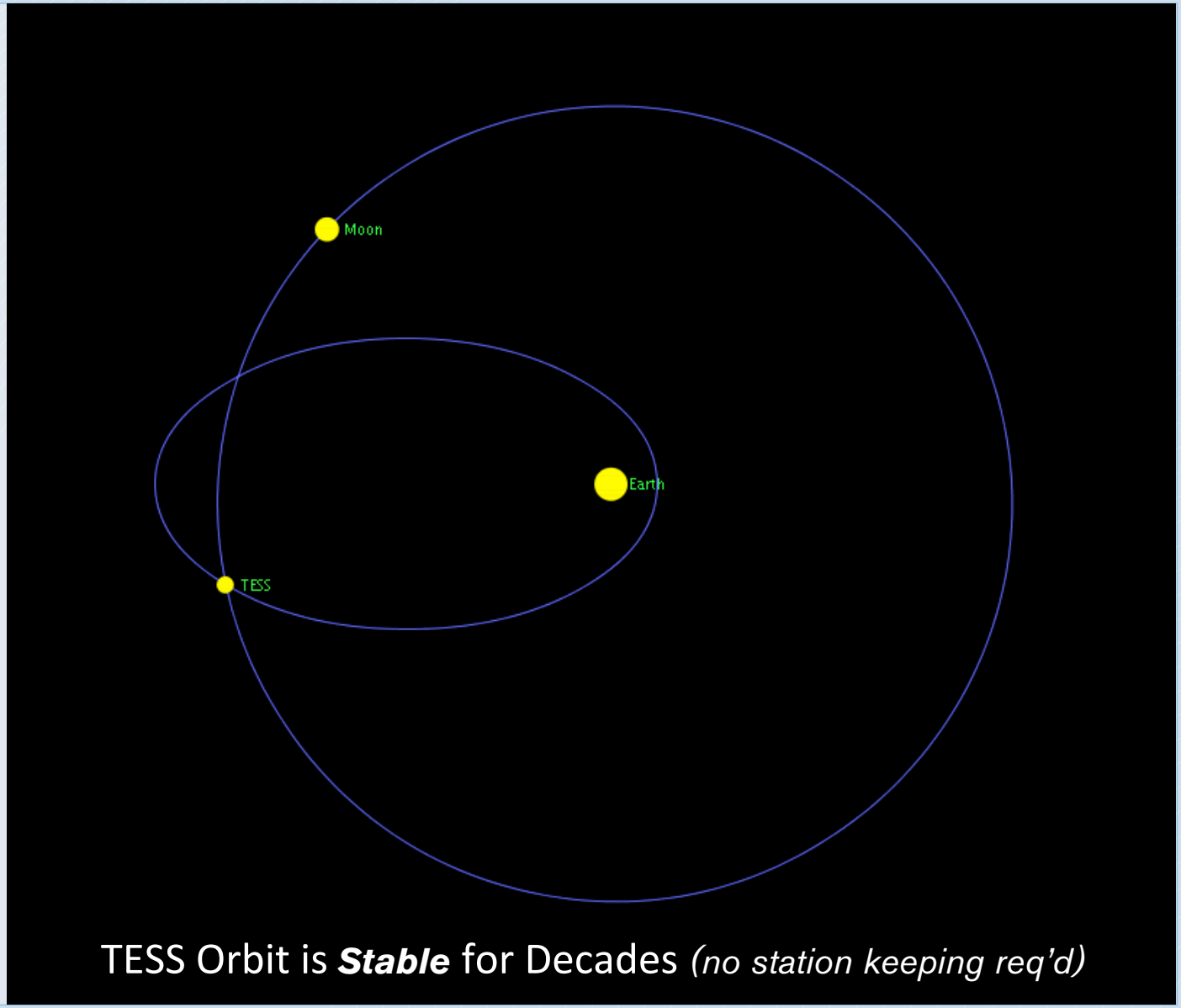
TRANSITING EXOPLANET SURVEY SATELLITE

MISSION ORBIT INSERTION

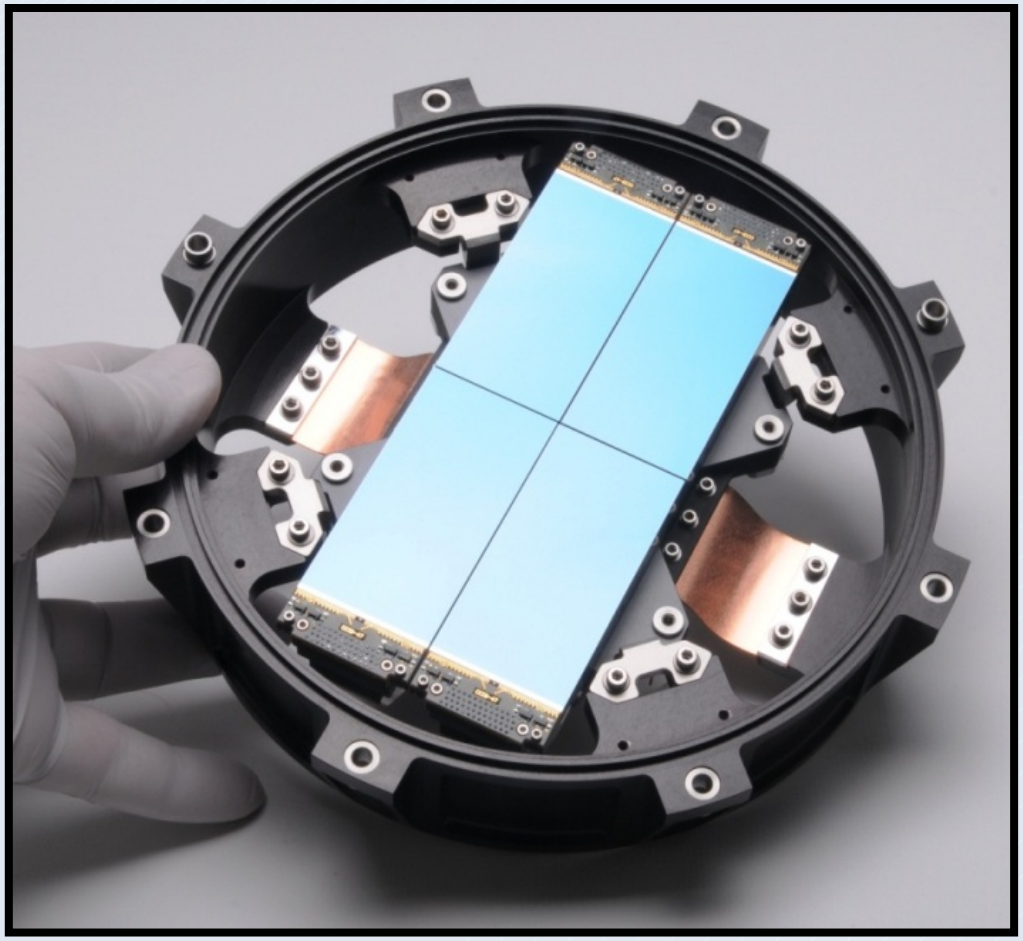
TESS's Novel High Orbit

Uninterrupted viewing for >95% of time

Orbital Periods:
TESS = 13.7 days
Moon = 27.4 days
➡ 2:1 Resonance
➡ 90° Phasing



TESS Orbit is ***Stable*** for Decades *(no station keeping req'd)*

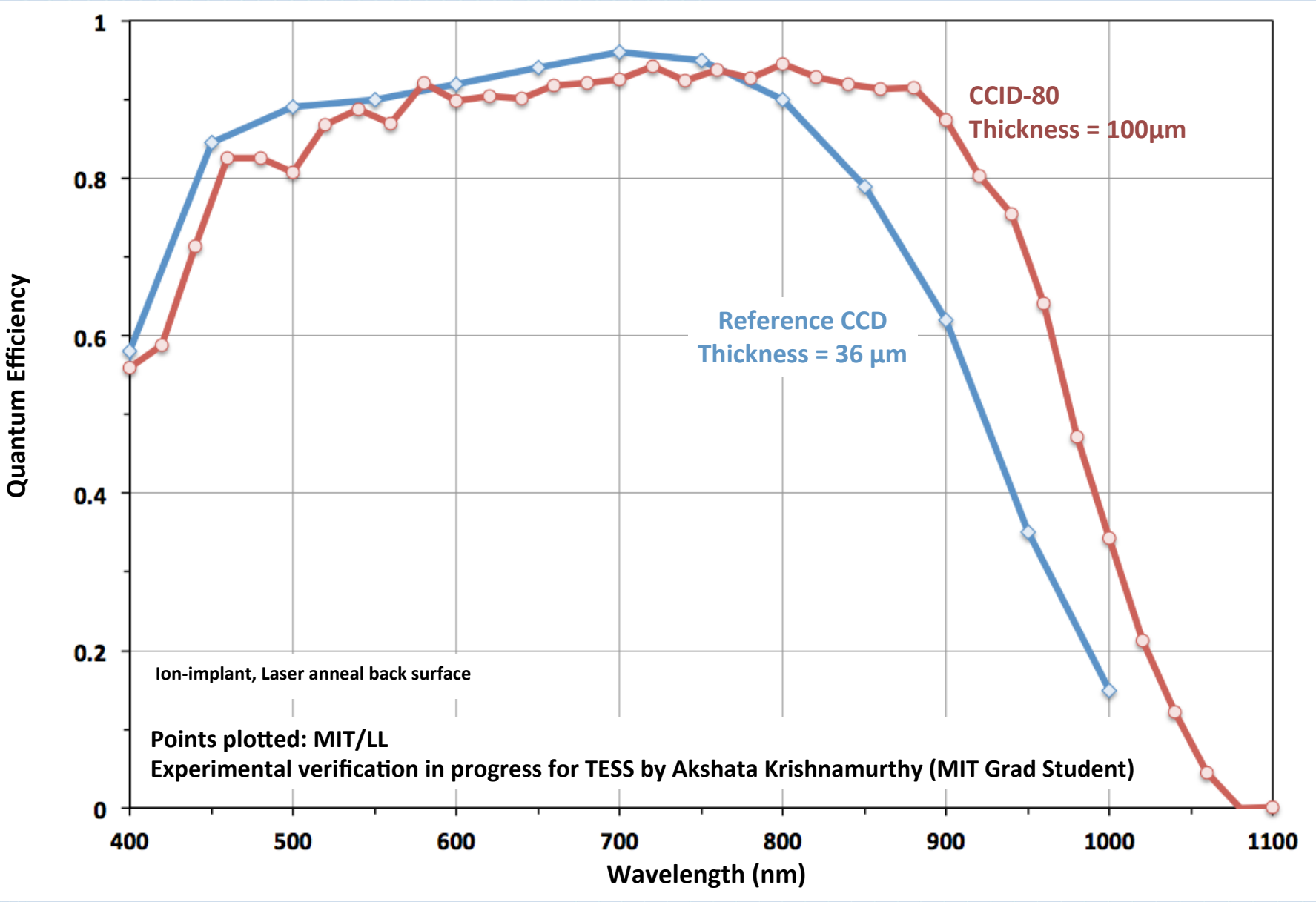


LL Deep Depletion CCDs

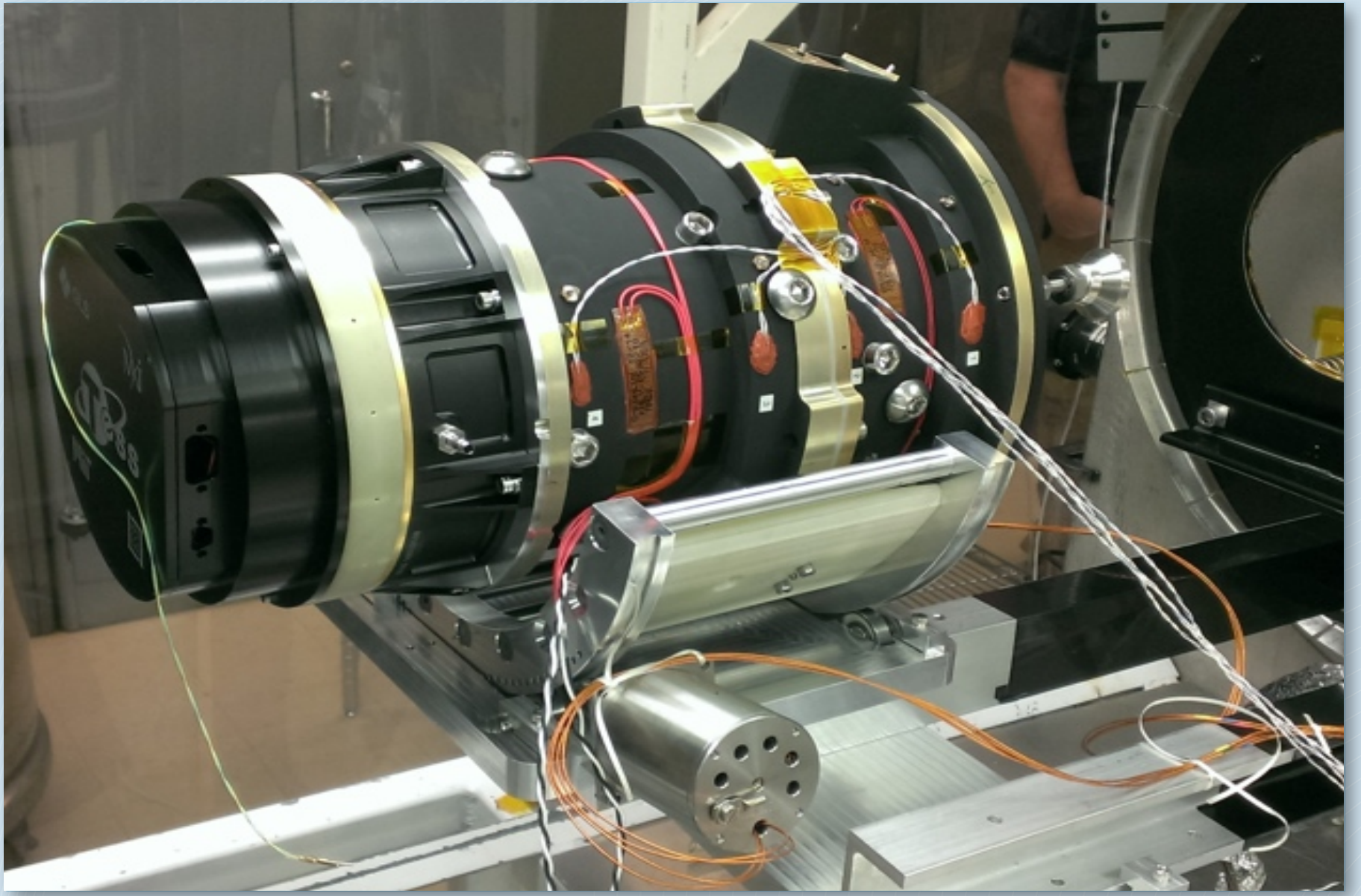
(Assembly by: GL Scientific)

Ricker et al. (2014)

Quantum Efficiency of BI CCID-80

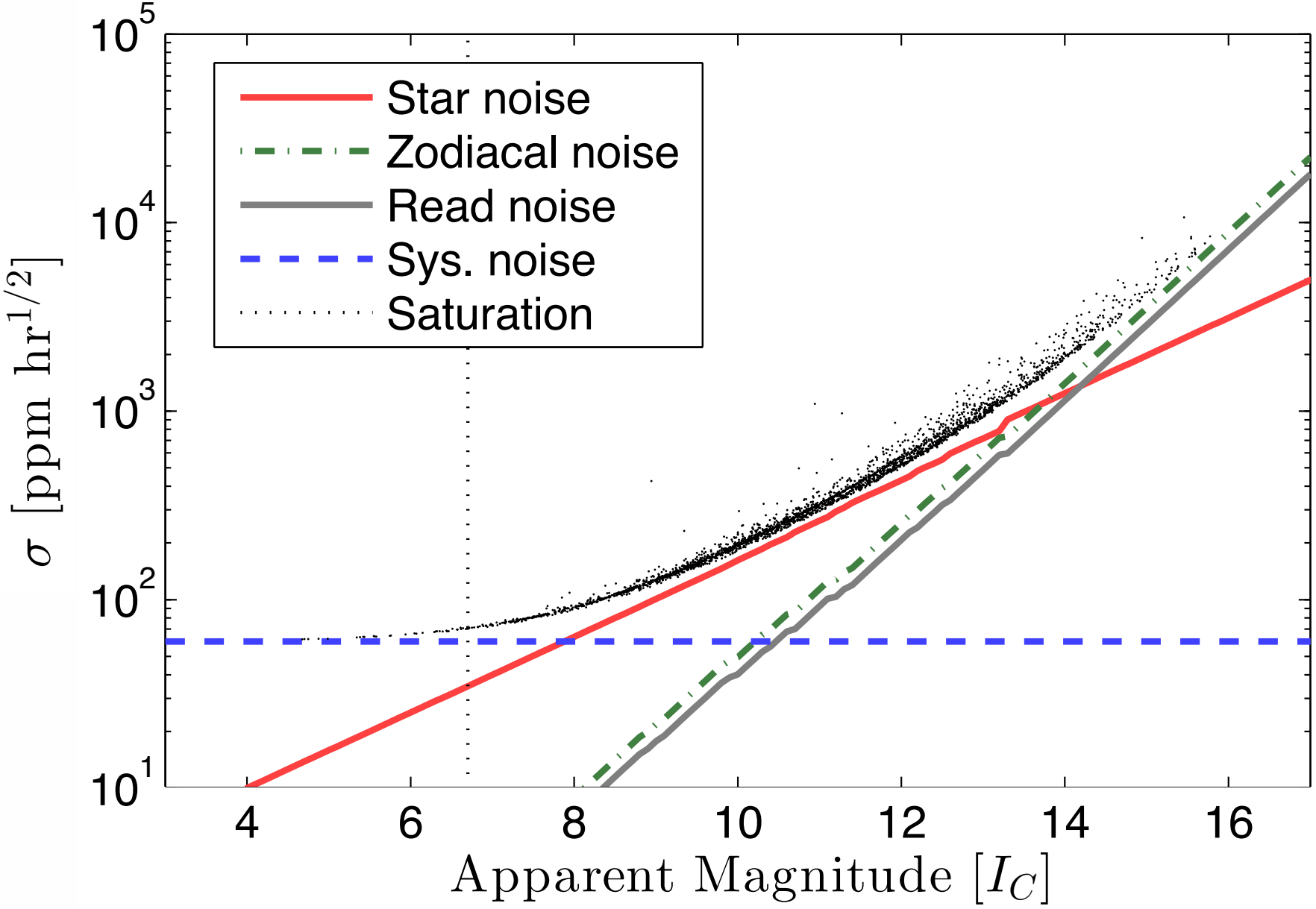


TESS Engineering Model Camera at MKI



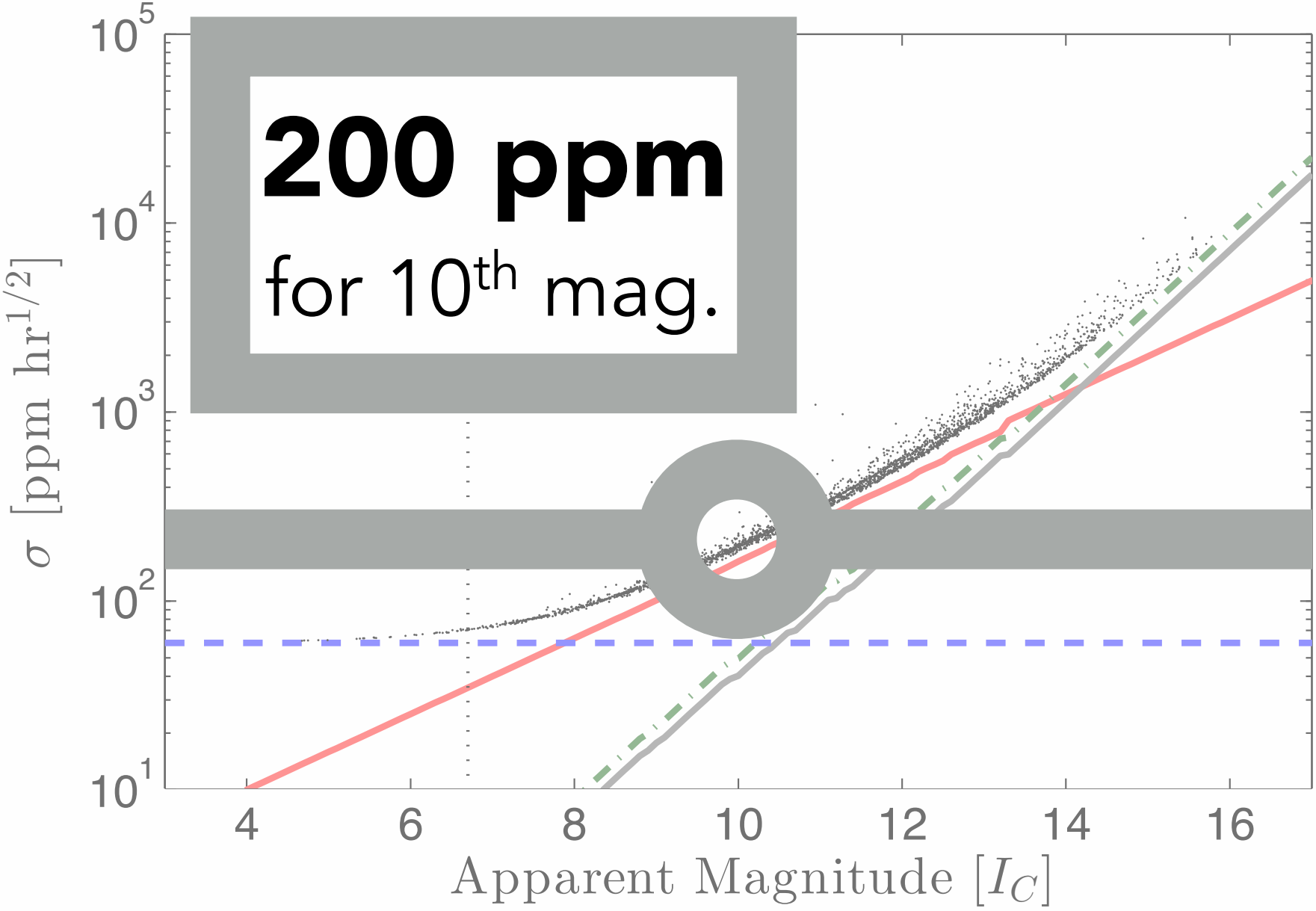
TESS Wide FOV CCD Camera Prototype

Photometric Noise in 1 Hour



Ricker et al. (2014)

Photometric Noise in 1 Hour



Ricker et al. (2014)

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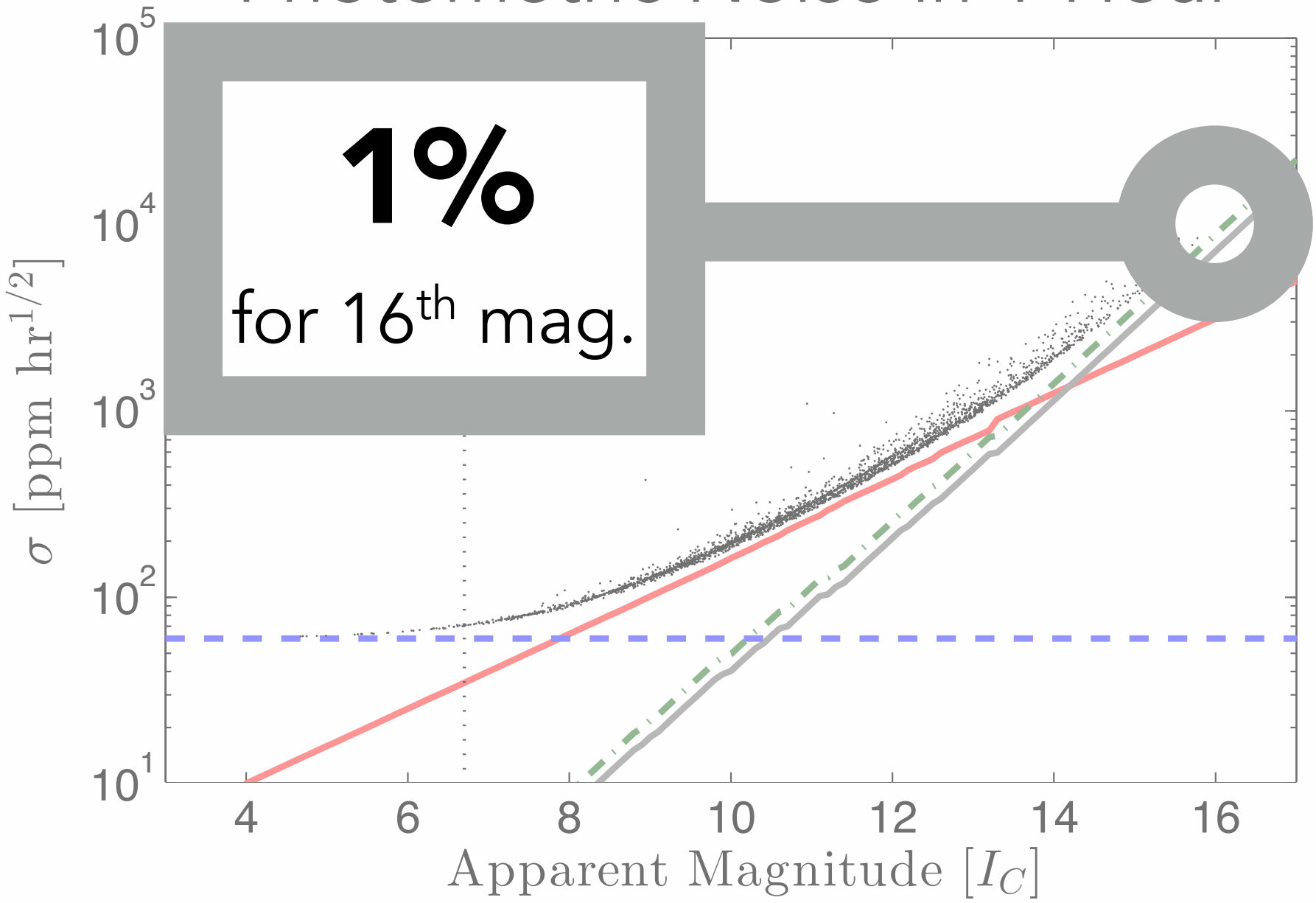
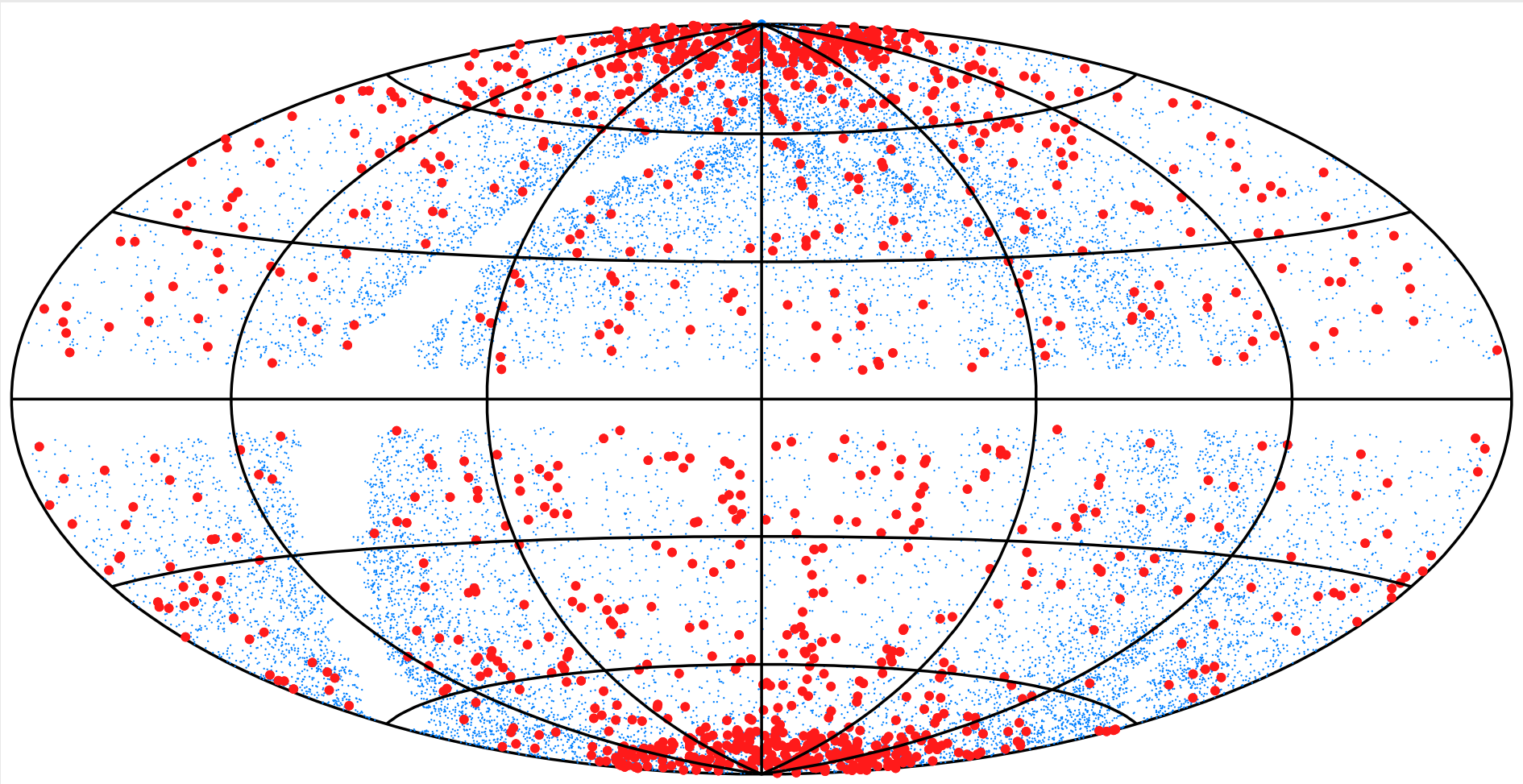


Ricker et al. (2014)

Simulated TESS detections



Ecliptic
Coordinates

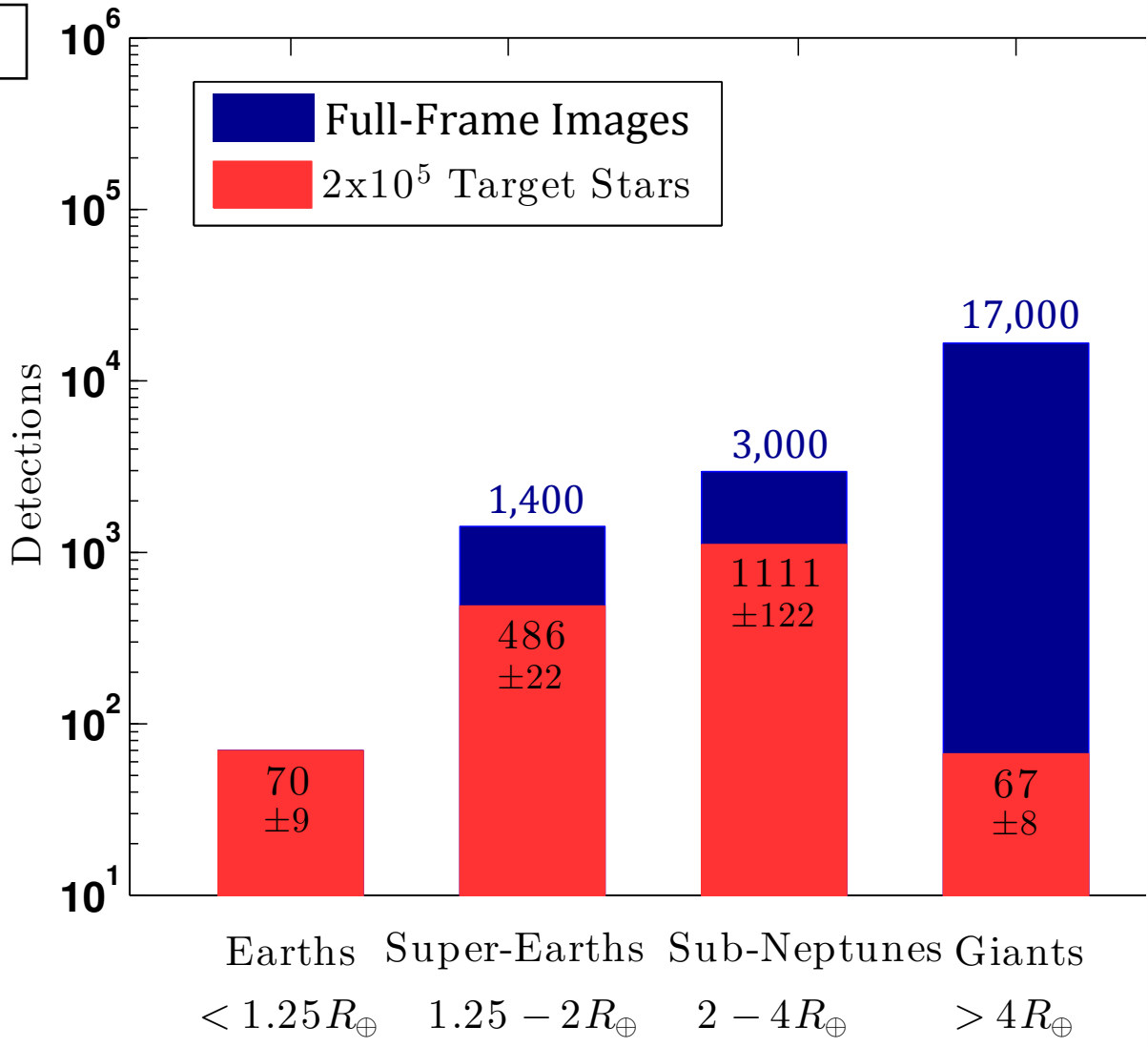
Sullivan et al. (arXiv:1506.08845)

Detectable planets around **200,000 pre-selected stars**

Detectable planets around **20,000,000 stars in full images**

The Predicted TESS Yield

NB: Log Scale on Y Axis



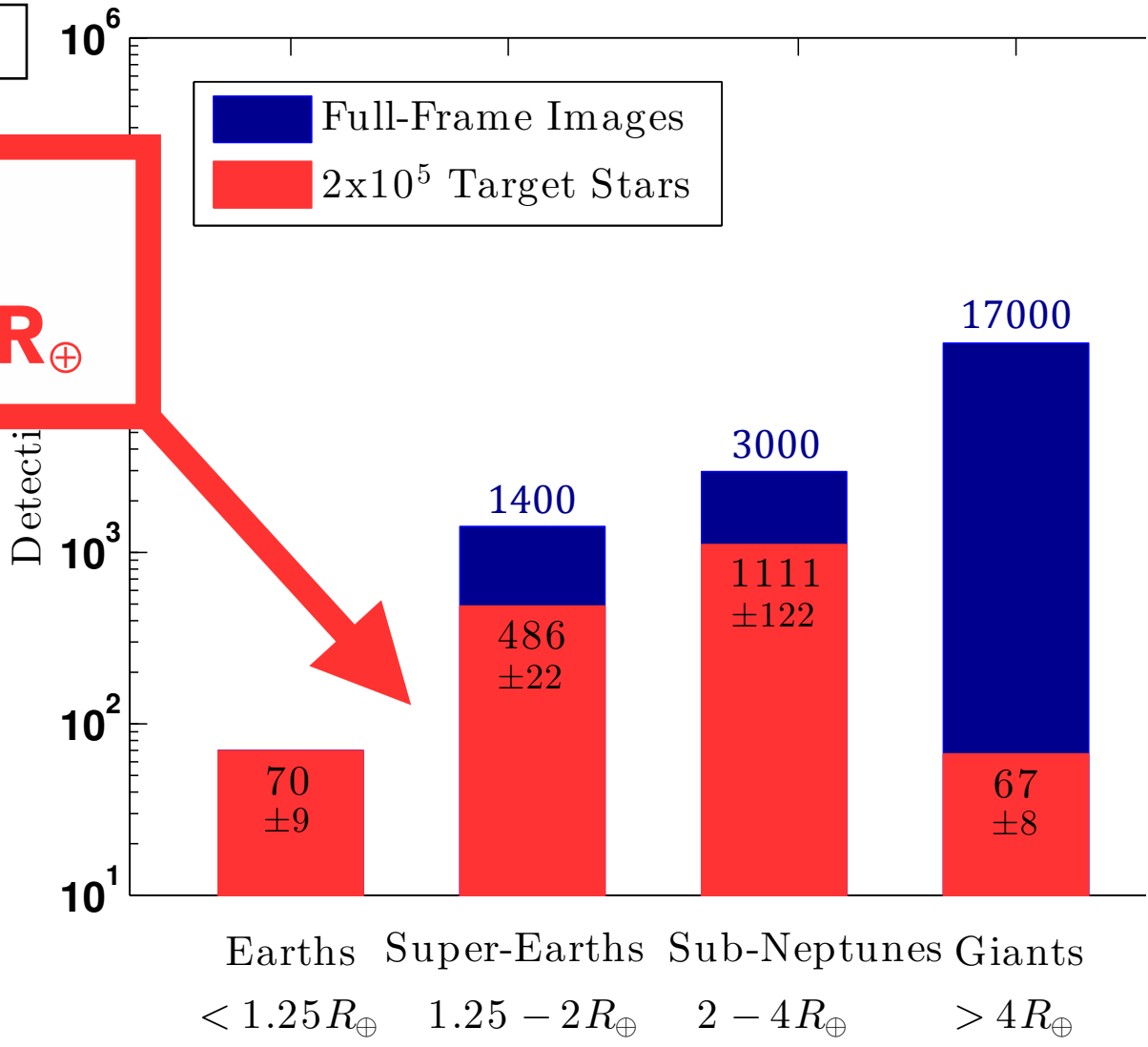
Sullivan et al. (arXiv:1506.08845)

The Predicted TESS Yield

NB: Log Scale on Y Axis

500 planets smaller than 2R⊕

mass measurements could resolve the rocky planet transition



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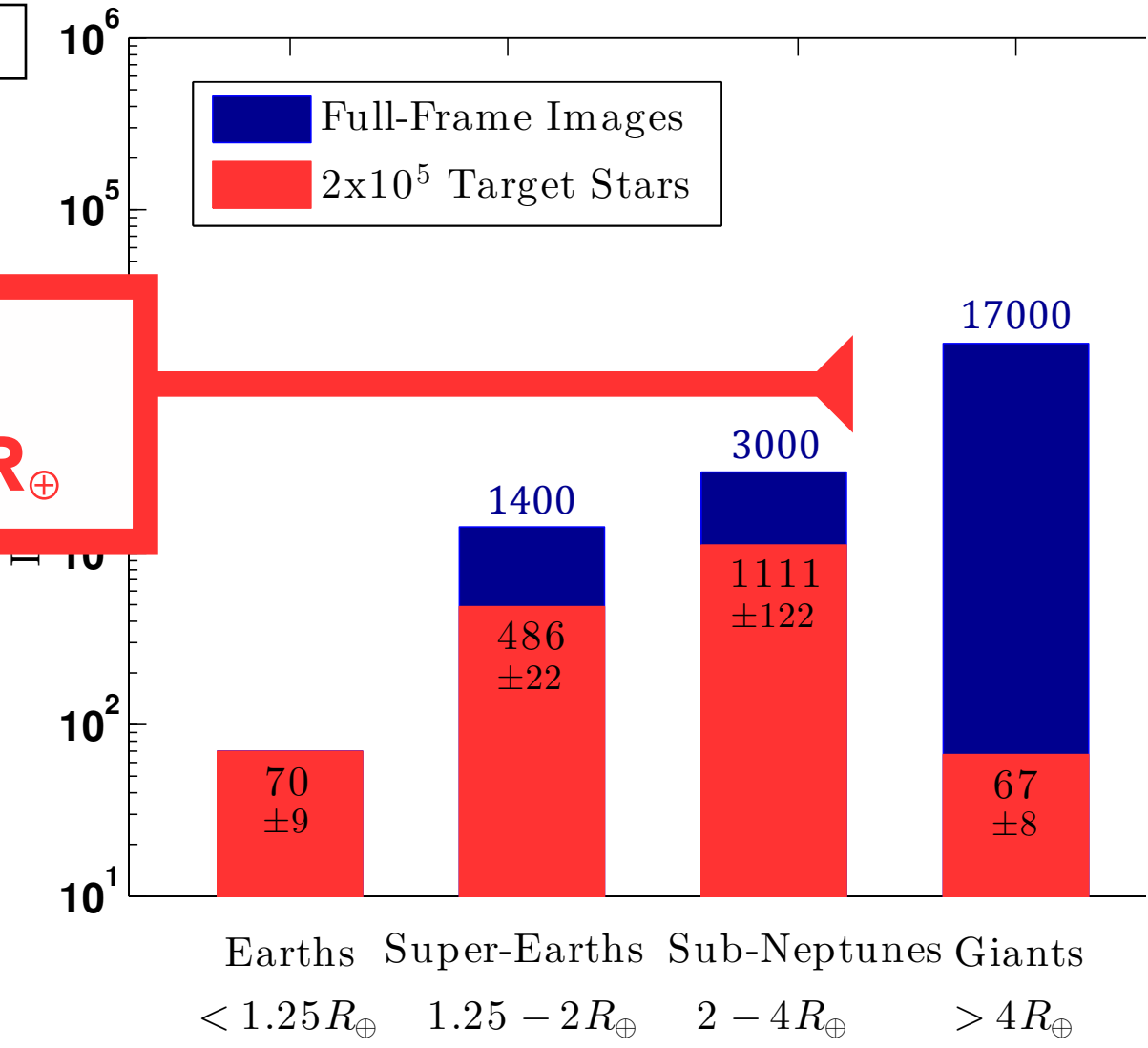
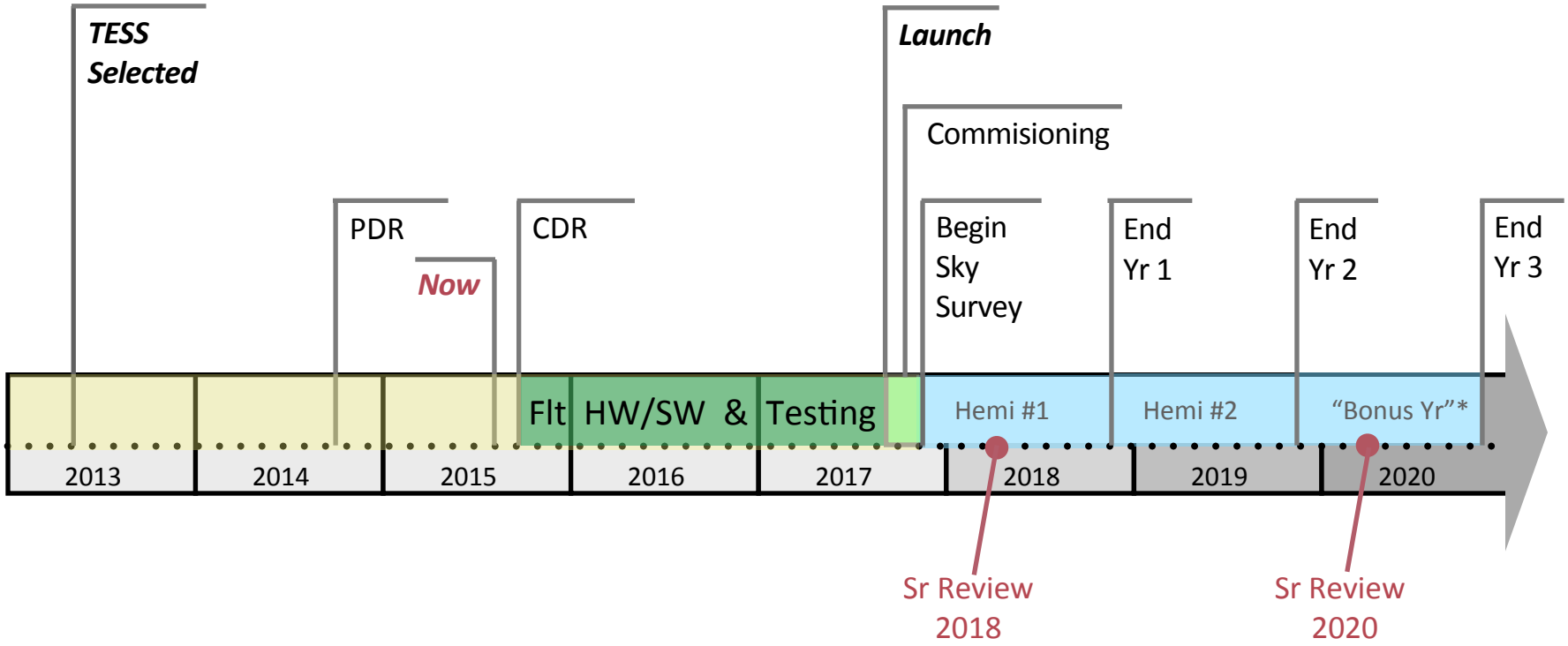


1500 planets smaller than $4R_\oplus$

atmospheric studies will be possible for many of these

Sullivan et al. (arXiv:1506.08845)

Timeline for TESS Mission



* 3rd "Bonus Year" of Survey:
Contingent on residual funds remaining from TESS mission reserves

** TESS itself (and the orbit) should be operable for more than a decade

Next Steps in TESS Science Planning

- Interacting with Other Initiatives and Missions:
  - *Providing for Non-Exoplanet Targets in TESS FFIs*
  - *Coordinating with Gnd Followup and TESS GO's*
  - *Partnering with K2 and CHEOPS*
  - *Providing Prime Followup Targets (JWST, ELTs)*
- Providing for Asteroseismology:
  - *~15,000 targets @ 2 min cadence*
  - *~1500 very bright targets @ 20 sec cadence (new mode)*
- Planning for Extended Mission(s):
  - *Repeat survey in a single hemisphere?*
  - *Concentrate on an ecliptic pole?*
  - *Concentrate on the ecliptic plane?*
    - *~5 x 72 day durations; comparable to ~ 100 K2 pointings*

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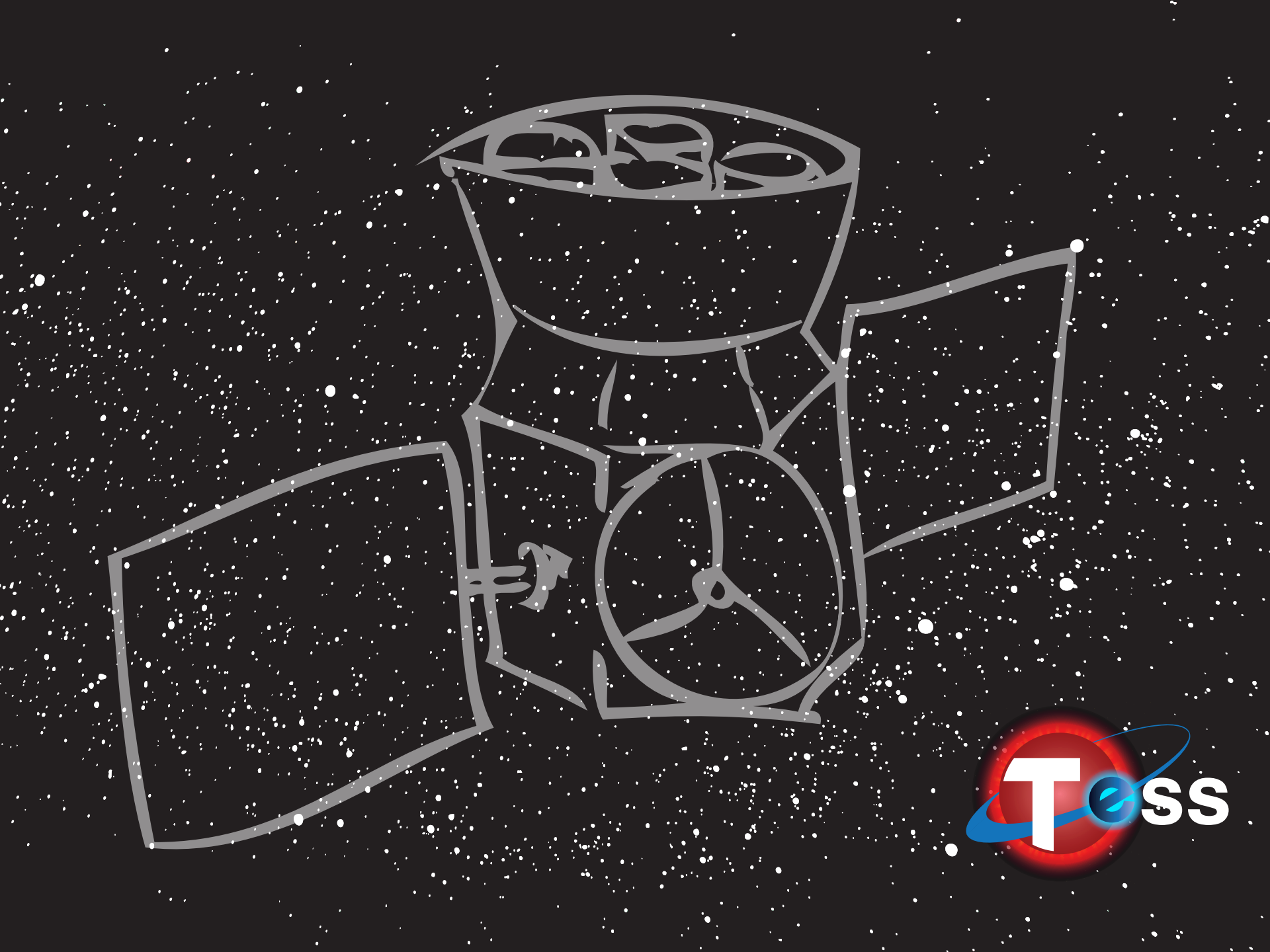
TESS